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THICKNESS COMPARISON FOR BUCKLING ANALYSIS OF STIFFENED CIRCULAR PLATE SUBJECTED TO IN- PLANE LOADING

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ABSTRACT

In the present investigation Numerical Simulation of Analysis of Buckling of Stiffened Circular Plates Subjected to In-Plane Loading has been done. Circular plate of radius of 0.5m and thickness of 0.005m of the plate is held constant for all the cases that are studied. The boundary conditions considered are such that the plate is fixed and released in radial direction. Stiffened circular plates subjected to the above loads and boundary conditions are numerically simulated using ABAQUS 6.10 version. Stiffeners of various cross sections were placed at different locations of circular plate to investigate their effectiveness in order to make economical. In all the analysis, a circular plate with T, HAT and I-shaped stiffeners are used. The effect of positioning I, T and HAT shape stiffeners on thin walled circular plates was studied using numerical method. A circular plate with T, HAT and I–shape as such one stiffener, two stiffeners, and three stiffeners with varying thickness of stiffeners are used. Height of stiffener is taken as 0.01m is constant of them. Thickness of the stiffener is taken as 0.002m to 0.008m with an interval of 0.001m. HAT and I-shape have width stiffener are taken constant as 0.01m. It is found that introducing a stiffening ring would result in higher buckling load, Increased in the number of stiffeners, leads to increase in the strength.

KEYWORDS: Buckling Load, ABAQUS6.10, Stiffened Plate, Circular Plate

INTRODUCTION

General

Thin plates are initially flat structural members bounded by two parallel planes, called faces, and a cylindrical surface, called an edge or boundary. The generators of the cylindrical surface are perpendicular to the plane faces. The distance between the plane faces is called the thickness of the plate. It will be assumed that the plate is a planar body whose thickness is small compared with other characteristic dimensions of the faces (length, width, diameter, etc.). Flat or slightly curved plates are frequently used elements in space-vehicle structure.Plates are used in architectural structures, bridges, hydraulic structures, pavements, containers, airplanes, missiles, ships, instruments, machine parts, etc. shown in Figure 1.The plates may be divided into individual groups according to the stress, specifically into:

- Thick plates.
- Medium thickness plates (Kirchhoff plates).
- Thin plates producing large deflections
- Diaphragms.

The "plate thickness" is considered in relation to the stress, prevailing stresses, and the method of handling [1].

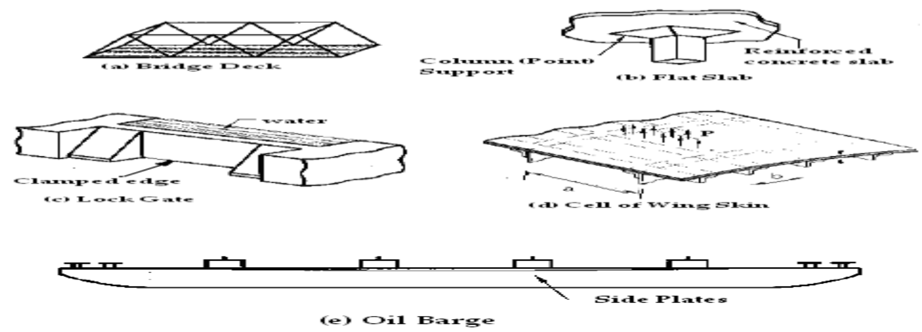

Figure 1: Plates Used in Different Engineering Structures

BUCKLING OF PLATES

Thin plates of various shapes used in naval and aeronautical structures are often subjected to normal compressive and shearing loads acting in the middle plane of the plate (in-plane loads). Under certain conditions such loads can result in a plate buckling. Buckling or elastic instability of plates is of great practical importance. The buckling load depends on the plate thickness: the thinner the plate, the lower is the buckling load. In many cases, a failure of thin plate elements may be attributed to an elastic instability and not to the lack of their strength. Therefore, plate buckling analysis presents an integral part of the general analysis of a structure. The transition of the plate from the stable state of equilibrium to the unstable one is referred to as buckling or structural instability. The smallest value of the load producing buckling is called the critical or buckling load [2 - 6].

STIFFENERS

Stiffeners are fastened to shells and plates to give the required design bending and buckling resistance at less weight than shells of uniform thickness i.e. monologue shells. Stiffeners also enable the shell to be tailored to the directional nature of the loading environment. For example, rings are also called frames, are added instead of increasing the shell thickness when the predominant loading is external pressure so that unneeded axial stiffness is not provided. Similarly, axial stiffeners usually called stringers, but sometimes called longerons are used for predominantly axial compression loading and both rings and stringers are used for mixing load conditions. The basic objective of the various stiffener shapes is to get as much material as possible from the shell middle surface i.e., to increase the moment of inertia of the stiffener about its own centroid axis and to increase the parallel axis theorem stiffness contributions relative to the shell (reference surface). Stiffeners can be mounted on shells in several different orientations relative to the shell axes. Stiffeners that are mounted in the axial and circumferential directions as shown in Figure 2 [7 - 9].

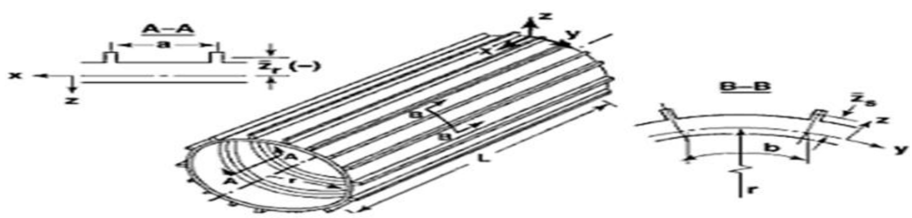

Figure 2: Orthogonally Stiffened Circular Cylindrical Shell

In Figure 2, sections A-A and B-B are used to define the ring spacing a, the stringer spacing b, the distance from the shell middle surface to the ring centroid Zr ,the ring eccentricity and the distance from the shell middle surface to the stringer centroid Zg, the stringer eccentricity in addition to the usual shell length, radius and thickness. Spirally oriented or helically oriented stiffeners studied by Soong and by Vasiliev are depicted in Figur3.Such spiral stiffeners can even be used without a shell in a grid form called a lattice to carry very high axial loads as in missile interstage structure [10 - 12].

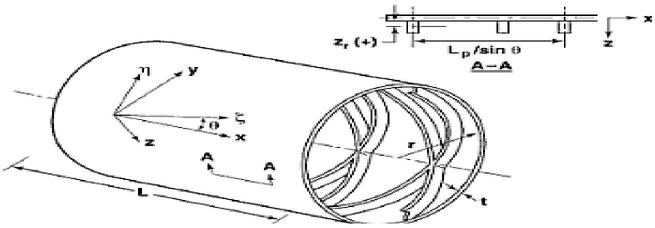

Figure 3: Helically Stiffened Circular Cylindrical Shells

Applications Circular and Stiffened Plates

- Construction of land based structures such as box girder and plate girder bridges
- Aeronautic and space shuttles among other structures. etc
- Stiffened plates are basic structural members in ship offshore and bridge structures as shown in figure 4
- Turbine disks.
- Bulkheads in submarines and airplanes.
- Nozzle covers.
- End closures in pressure vessels.
- Pump diaphragms [13].

Figure 4: Some Examples of Application Stiffened Plate

ASSUMPTION SYSTEM AND SIMULATIONS

Classical Theory of Plate

Circular plates in some measuring instruments are used as sensitive elements reacting to a change in the lateral pressure. In some cases – in temperature changes, in the process of their assembly – these elements are subjected to the action of radial compressive forces from a supporting structure. As a result, buckling of the circular plates can take place.

Circular Plate Subjected to Uniformly Distributed Inplane Compressive Radial Forces

Let us consider a circular solid plate subjected to uniformly distributed in-plane compressive radial forces q_r, as shown in Figure 5. We confine our buckling analysis to considering only axisymmetric configurations of equilibrium for the plate. We can use the polar coordinates r and Ø to transfer the governing differential equation of plate buckling Equation.

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{1}{D}\left(N_x \frac{\partial^2 w}{\partial x^2} + 2N_{xy}\frac{\partial^2 w}{\partial x \partial y} + N_y \frac{\partial^2 w}{\partial y^2}\right)$$

This is derived for a rectangular plate, to a circular plate. For the particular case of axisymmetric loading and equilibrium configurations we have

$$N_x = N_y = N_r = -q_r,\ N_{xy}=0 \tag{1}$$

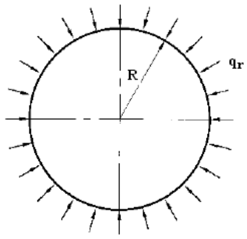

Figure 5: Circular Plate Subjected to Uniformly Distributed in Plane Compressive Radial Forces

$$\mu^2 = \frac{q_r}{D} \tag{2}$$

Denoting and using the relations between the polar and Cartesian coordinates, we obtain the following differential equation of the axisymmetrically loaded circular plate subjected to in-plane compressive forces q_r:

$$\frac{d^4w}{dr^4} + \frac{2}{r}\frac{d^3w}{dr^3} - \frac{1}{r^2}\frac{d^2w}{dr^2} + \frac{1}{r^3}\frac{dw}{dr} + \mu^2\left[\frac{d^2w}{dr^2} + \frac{1}{r}\frac{dw}{dr}\right] = 0 \tag{3}$$

Let us introduce the following new variable:

$$\rho = \mu r \tag{4}$$

Which represents a dimensionless polar radius. Using the new variable ρ, we can rewrite Equation (3) as follows:

$$\frac{d^4w}{d\rho^4} + \frac{2d^3w}{\rho d\rho^3} + \left(1-\frac{1}{\rho^2}\right)\frac{d^2w}{d\rho^2} + \frac{1}{\rho}\left(1+\frac{1}{\rho^2}\right)\frac{dw}{d\rho} = 0 \tag{5}$$

This is a fourth-order linear, homogeneous differential equation. The general solution of this equation is given as

$$w(\rho) = C_1 + C_2 \ln \rho + C_3 J_0(\rho) + C_4 Y_0(\rho) \tag{6}$$

Where J_0 (ρ) and Y_0 (ρ) are the Bessel functions of the first and second kind of zero orders, respectively. In equation (6), C_i (i =1 . . . 4) are constants of integration. Since w (ρ) must be finite for all values of ρ, including ρ= 0, then the two terms in ρ and Y_0 (ρ), having singularities at ρ=0, must be dropped for the solid plate because they approach an infinity when ρ→∞. Thus, for the solid circular plate, Equation (6) must be taken in the form

$$w(\rho) = C_1 + C_3 J_0(\rho) \tag{7}$$

Determine the critical values of the radial compressive forces, q_r, applied to the middle plane of solid circular plates for two types of boundary supports [1], [14], [15].

FEA / Finite Element Analysis

The finite element method is a numerical procedure for analyzing structures and continua. Usually problem addressed is too complicated to be solved satisfactorily by classical analytical methods. The finite element procedure develops many simultaneous algebraic equations, which are generated and solved on a digital computer. The results obtainable are accurate enough for engineering purposes at reasonable cost. In addition, it is an efficient design tool by which designers can perform parametric design studies by considering various design cases (different shapes, materials, loads, etc..,), analyze them and choose the optimum design. Hence the method has increasingly gained popularity among both researchers and practitioners [16].FEA is the modeling of products and systems in a virtual environment, for the purpose of finding and solving potential (or existing) structural or performance issues. FEA is the practical application of

the finite element method (FEM), which is used by engineers and scientist to mathematically model and numerically solve very complex structural, fluid, and multiphasic problems. FEA Software can be utilized in a wide range of industries, but is most commonly used in the aeronautical, biomechanical and automotive industries. A finite element (FE) model comprises a system of points, called “nodes”, which form the shape of the design. Connected to these no des are the finite elements themselves which form the finite element mesh and contain the material and structural Properties of the model, defining how it will react to certain conditions. The density of the finite element mesh may vary throughout the material, depending on the anticipated change in stress levels of a particular area. Regions that experience high changes in stress usually require a higher mesh density than those that experience little or no stress variation. Points of interest may include fracture points of previously tested material, fillets, corners, complex detail, and high-stress areas. FE models can be created using one-dimensional (1D beam), two-dimensional (2DShell) or three-dimensional (3D solid) elements. By using beams and shells instead of Solid elements, a representative model can be created using fewer nodes without compromising accuracy. To simulate the effects of real-world working environments in FEA, various load types can be applied to the FE model, including [17], [18].

- Nodal: forces, moments, displacements, velocities, accelerations, temperature and heat flux.
- Elemental: distributed loading, pressure, temperature and heat flux
- Acceleration body loads (gravity)

About ABAQUS

Abaqus is a suite of powerful engineering simulation programs, based on the finite element method, that can solve problems ranging from relatively simple linear analysis to the most challenging nonlinear simulations. Abaqus contains an extensive library of elements that can model virtually any geometry. It has an equally extensive list of material models that can simulate the behavior of most typical engineering materials including metals, rubber, polymers, composites, reinforced concrete, crushable and resilient foams, and geotechnical materials such as soils and rock. Designed as a general-purpose simulation tool, Abaqus can be used to study more than just structural (stress/displacement) problems. It can simulate problems in such diverse areas as heat transfer, mass diffusion, thermal management of electrical components (coupled thermal-electrical analyses), acoustics, soil mechanics (coupled pore fluid-stress analyses), piezoelectric analysis, electromagnetic analysis, and fluid dynamics .Complete ABAQUS Environment(CAE) provides a simple, consistent interface for creating Abaqus models, interactively submitting and monitoring Abaqus jobs, and evaluating results from ABAQUS simulations [19].

ABAQUS/CAE

ABAQUS/CAE (Complete ABAQUS Environment) is an interactive, graphical Environment for Abaqus. It allows models to be created quickly and easily by Producing or importing the geometry of the structure to be analyzed and decomposing. The geometry into mesh able regions. Physical and material properties can be assigned to the geometry, to gether with loads and boundary conditions. Abaqus/CAE contains very powerful options to mesh the geometry and to verify the resulting analysis model. Once the model is complete, Abaqus/CAE can submit, monitor, and control the analysis jobs. The Visualization module can then be used to interpret the results [20]. A complete Abaqus analysis usually consists of three distinct stages: preprocessing, simulation, and post processing. These three stages are linked together by files as shown in figure 6 [19].

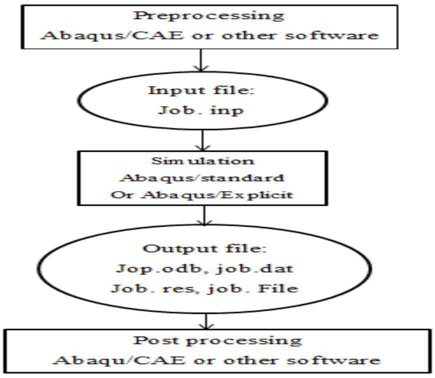

Figure 6: Stages are Linked Together

Element Choice

Another important issue in computational simulations is the selections of element types that are used to discretize the structure. ABAQUS offers a number of structural element types, of which thin shell elements were identified as potential candidates for modeling membrane structures.ABAQUS provides a number of three dimensional shell elements, which can be classified into two types, conventional shell element and continuum shell element. Conventional shell elements discretize a body by defining the geometry at a reference surface, and have displacement and rotational degrees of freedom. In contrast, a continuum shell element discretizes an entire three-dimensional body, and has only displacement degrees of freedom. For general purposes, the former provides robust and accurate solutions to most application. Figure 7 shows the installation of the element [19]

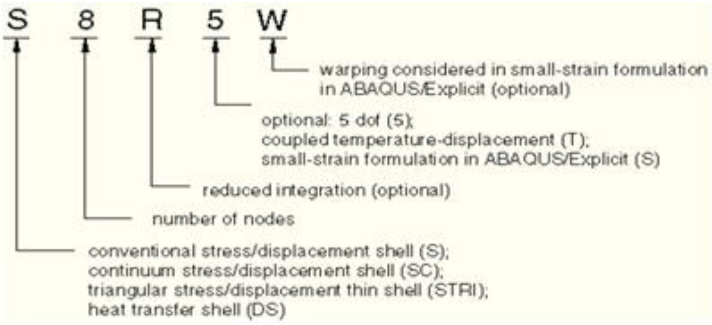

Figure 7: Three Dimensional Shell Element Name Convention in ABAQUS

S4, S4R and S3 Elements, These elements are part of the commercial software ABAQUS and are based on a thick shell theory. They serve as general-purpose shell elements in the ABAQUS element library. The shell formulation considered is that of finite-membrane strain; therefore, these elements can be used to perform large strain analyses. They are widely used for industrial applications because they are suitable for both thin and thick shells. It is thus useful to compare their performance with that of the other shell elements presented above. The S4 element uses a normal integration rule with four integration points. The assumed strains approach is employed to prevent shear and membrane locking. The S4R element uses a reduced integration rule with one integration point that makes this element computationally less expensive than S4. For S4R, the assumed strains method is modified, so that a one point integration scheme plus hourglass stabilization is obtained. Hourglass modes, a form of artificial mechanisms, can arise from the use of the reduced integration rule. The hourglass stabilization is performed through an hourglass control parameter. The S3 element is obtained through the degeneration of the S4 element and thus, “may exhibit overly stiff response in membrane deformation,” as discussed in ABAQUS. The ABAQUS shell library also includes the general purpose S3R element. This element is equivalent to S3, yielding identical results to those of S3 for all the problems investigated in this paper.

More details can be found about these four elements in ABAQUS. The S4R element has some properties as shown in figure 8 [19]:

- Uniformly reduced integration to avoid shear and membrane locking.
- The element has several hourglass modes that may propagate over the mesh.
- Converges to shear flexible theory for thick shells and classical theory for thin shells.

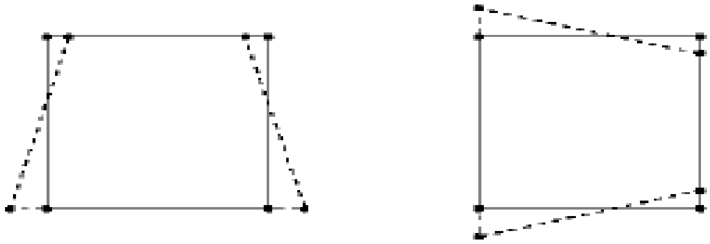

Figure 8: S4R Element Type in ABAQUS Software

Mild Steel

The term steel is used for many different alloys of iron. These alloys vary both in the way they are made and in the proportions of the materials added to the iron. All steels, however, contain small amounts of carbon and manganese. In other words, it can be said that steel is a crystalline alloy of iron, carbon and several other elements, which hardens above its critical temperature. Like stated above, there are exist several types of steels which are (among others) plain carbon, stainless steel, and alloy steel, tool steel and mild steel. Mild steel is a type of steel alloy, that contains a high amount of carbon as a major constituent. An alloy is a mixture of metals and non-metals. A high amount of carbon makes mild steel different from other types of steel. Carbon makes mild steel stronger and stiffer than other type of steel. However, the hardness comes at the price of a decrease in the ductility of this alloy. Carbon atoms get affixed in the interstitial sites of the iron lattice and make it stronger. Mild steel is the cheapest and most versatile form of steel and serves every application which requires a bulk amount of steel. The high amount of carbon, also makes mild steel vulnerable to rust. Naturally, people prefer stainless steel over mild steel, when they want a rust free technology. Mild steel is also used in construction as structural steel. It is also widely used in the car manufacturing industry as shown in figure 9. Mild steel can also be used to manufacture Bullets, Nuts & bolts, Chains, Hinges, Knives, Armor, and Pipes, Magnets etc.

Iron named 52 this means that resistance to flatten 52 kg / mm ^{2} and a yield strength of at least 36 kg / cm ^{2} and elongation at break of 18%, is used in heavy establishments as it is characterized by the following [20].

- Serrated.
- There is in the form of shingles.
- Can only be formed only once.
- There are in the market for body lengths.

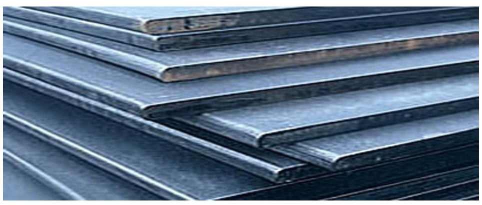

Figure 9: Mild Steel Sheets

Modeling Methods

All finite element method (FEM) complete by using version 6.10 of the ABAQUSsoftware package. The four-node, doubly curved linear element library .shell elements chosen over three dimensional elements in order to maintain acceptable element aspect ratios with a reasonable mesh density.Circular plate with stiffeners subjected to radial axial compressive load applied is **20KN**. It should be noted that plate is fixed but released in radial direction. With this, the basic problem addressed in the work may be stated as follows:

Circular with dimensions is taken and three different stiffeners **T, HAT and I-Shape** are chosen for stiffening of the cover plate of the structure. A material for circular plate and stiffeners are chosen is mild steel. The FEM analysis is carried-out in **ABAQUS 6.10.**

Important notes regarding the above problem are as follows:

- The circular plate is assumed to have constant radius and thickness.
- The thickness and sizes of stiffeners are varied for different models.
- The plate is assumed to be fixed but released in radial direction.
- The material chosen for Circular plate and stiffener is mild steel.
- The maximum principal stress values show the amount of stresses at various sections of plate and stiffeners.

Numerical Modeling and Analysis

The dimensions of the circular plate used were radius of 0.5m and thickness of 0.005m. The axial compressive load applied is 20kN. The boundary conditions were fixed but released in radial direction. The above parameters are kept constant throughout the analysis. The analysis had done for three different models of circular plate with stiffeners of different cross sections are considered

In First Model, circular plate with**T**-shape: a) One stiffener b) Two stiffener and c) Three stiffeners with varying thickness of stiffeners are considered. Height of stiffener is taken as 0.01m and is kept constant. Thickness of the stiffener is taken as 0.002m to 0.008m with an interval of 0.001m.

In Second Model, circular plate with **I**-shape: a) One stiffener b) Two stiffener and c) Three stiffeners with varying thicknesses of stiffeners are considered. Height of stiffener is taken as 0.01m and is kept constant. Thickness of the stiffener is taken as 0.002m to 0.008m with an interval of 0.001m. .Width of stiffener is taken as 0.01m and is kept constant.

In Third Model, circular plate with **HAT**-shape: a) One stiffener b) Two stiffener and c) Three stiffeners with varying thicknesses of stiffeners are considered. Height of stiffener is taken as 0.01m and is kept constant. Thickness of the stiffener is taken as 0.002m to 0.008m with an interval of 0.001m. Width of stiffener is taken as 0.01m and is kept constant.

Material Selection

The material chosen for cover plate and stiffener is mild steel.

Material Properties

Mild steel:

Young's modulus, **E=200GPa**

Poisson's ratio, ν **=0.3**

Creating the Mesh and Defining a Job

Seed the part with a global element size of 0.035. Mesh the plate and stiffeners using quadrilateral shell elements (S4R) from the explicit element library **(S4R: A4-node doubly curved thin or thick shell, reduce integration, hourglass control, finite member strains).** The resulting mesh is shown in figure 10.

Create a job named circular plate.cae. Save your model in a model database file, and submit the job for analysis. Monitor the solution progress; correct any modeling errors that are detected, and investigate the cause of any warning messages.

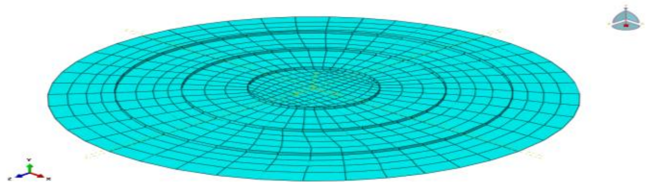

Figure 10: Meshing for Stiffened Circular Plate (T-Shape Stiffener)

RESULTS AND DISCUSSIONS

Case 1: Circular Plate with T-Shape Stiffeners with Varyingthickness

In this case stiffened circular plate of mild steel is subjected to axial compression for various thicknesses of stiffener under the boundary conditions fixed but released in radial direction. The values are tabulated in below. In the tables the buckling load of the circular plate is increasing with increase in the number of stiffeners. And the buckling load is increasing with increase in the mode shape as in figure 11, the same result in table1.

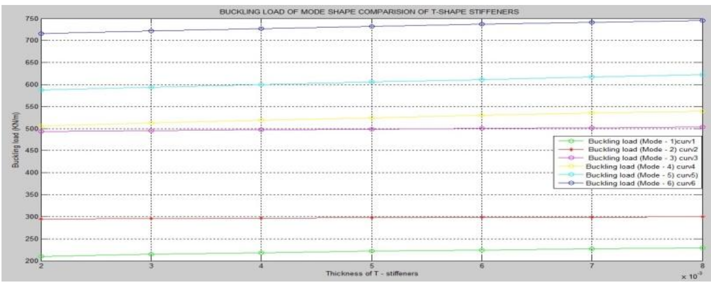

Figure 11: Buckling Load of Mode Shape of T-Shape Stiffeners

Table 1: (Figure 11 & 12) Buckling Loads for T–Shape ONE- STIFFENER

Thickness(M)	Axial Compressive Load (KN/M)	ONE - STIFFENER					
		1	2	3	4	5	6
0.002	20	210	295.2	493.58	505.92	587.16	715.56
0.003	20	214.38	295.92	495.44	512.6	593.9	721.66
0.004	20	218.18	296.78	497.2	518.7	600.14	726.98
0.005	20	221.54	297.6	498.88	524.4	606	732
0.006	20	224.52	298.36	500.46	529.8	611.66	736.8
0.007	20	227.16	299.08	501.94	534.96	617.18	741.34
0.008	20	229.52	299.76	503.34	539.86	622.56	745.62

The thickness of the stiffeners is increasing from 0.002 to 0.008 for all the three cross- section **(T, I, HAT - shape)** of the stiffeners. And also the numbers of stiffener with one, two and three stiffeners.

- With the increase in the number of **T shape** stiffeners from **one to two** the percentage increase in the buckling strength is from **3% to 4%** for **0.002m** thick stiffener. However the percentage increase in the buckling strength is from **17% to 18%** for **0.008m** thick stiffener. The buckling strength very much in flounced by the thickness of stiffeners and number of stiffener.

- With the increase in the number of **T-shape** stiffeners from **one to three,** the percentage increase in the buckling strength is from **5% to 6%** for **0.002m** thick stiffener. However the percentage increase in the buckling strength is from **26% to 27**% for **0.008m** thick stiffener. The buckling strength very much in flounced by the thickness of stiffeners and number of stiffener as shown figure 12.

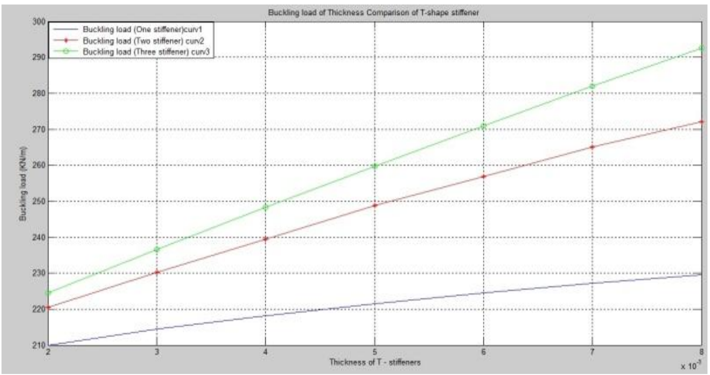

Figure 12: Buckling Load of Comparisons of T-Shape Stiffener

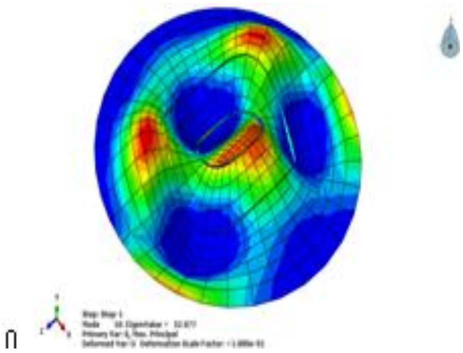

Figure 13: Deformed T-Shape with Two Stiffeners of Thickness t=0.002m for Mode-10

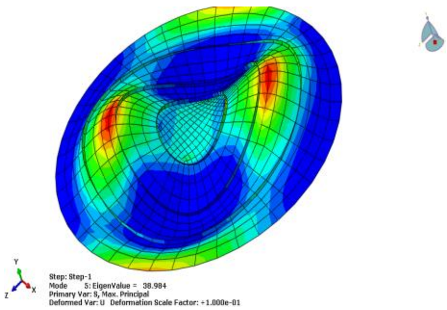

Figure14: Deformed T-Shape with Three Stiffeners of Thickness t=0.008m for Mode-5

Case 2: Circular Plate with I-Shape Stiffeners for Different Cross Sections of Stiffeners with Varying Thickness. Height of Stiffener is Taken as 0.01m and is Kept Constant

In this case stiffened circular plate of mild steel is subjected to axial compression for various thicknesses of stiffeners are considered under the boundary conditions, fixed but released in radial direction. The values are tabulated in. In the tables in below. The buckling load of the circular plate is increasing with increase in the number of stiffeners. And the buckling load is increasing with increase in the mode shape as in given by figure 15 as result from table 2.

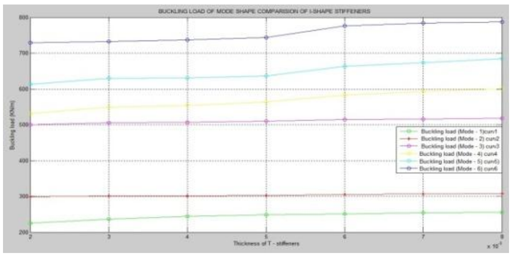

Figure 15: Buckling load of Mode Shape of I-Shape Stiffeners

Table 2: (Figure 15 & 16) Buckling loads for I–Shape ONE -Stiffener

THICKNESS(m)	Axial Compressive load (KN/m)	ONE - STIFFENER					
		1	2	3	4	5	6
0.002	20	224.9	298.8	500.42	531.16	613.24	728.82
0.003	20	235.92	301.46	505.52	549.38	629.6	732.12
0.004	20	244.02	301.36	503.8	553.54	626.48	736.34
0.005	20	248.72	302.66	506.32	563.26	635.9	743.02
0.006	20	251.06	305.84	514.1	582.28	662.42	775.96
0.007	20	253.78	307.12	516.12	592.6	673.72	783.46
0.008	20	255.8	307.44	517.46	600.02	683.98	787.34

The thickness of the stiffeners is increasing from 0.002 to 0.008 for all the three cross- section (T, I, HAT - shape) of the stiffeners. And also the numbers of stiffener with one, two and three stiffeners**.**

- With the increase in the number of I-shape stiffeners from one to two, the percentage increase in the buckling strength is from 17% to 18% for 0.002m thick stiffener. However the percentage increase in the buckling strength is from 45% to 50% for 0.008m thick stiffener.
- With the increase in the number of I-shape stiffeners from one to three, the percentage increase in the buckling strength is from 25% to 26% for 0.002m thick stiffener. However the percentage increase in the buckling strength is from 85% to 90% for 0.008m thick stiffeneras shown figure 16.

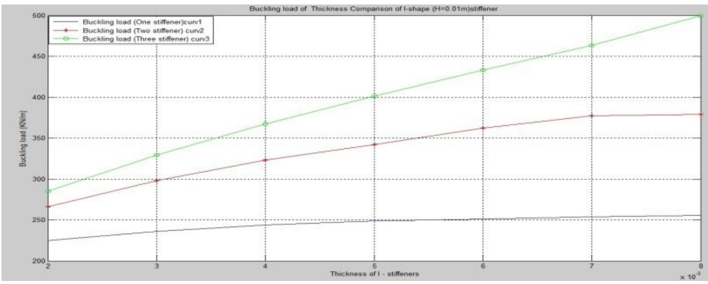

Figure 16: Buckling Load of Comparisons of I-Shape Stiffener

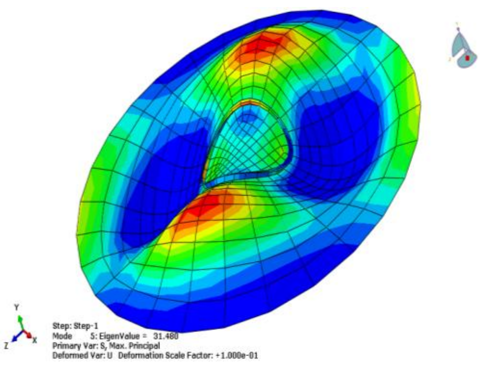

Figure 17: Deformed I-Shape, One Stiffener of Thickness t=0.003m, h=0.01m for Mode-5

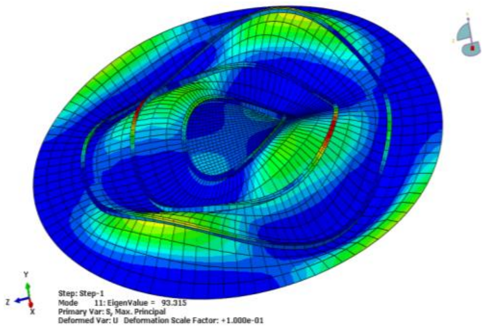

Figure 18: Deformed I-Shape, Three Stiffeners of Thickness t=0.007m, h=0.01 for Mode-11

Case 3: Circular Plate with Hat-Shape Stiffeners for Different Cross Sections of Stiffeners with Varying Thickness. Height of Stiffener is Taken as 0.01m and is Kept Constant

In this case stiffened circular plate of mild steel is subjected to axial compression for various thicknesses of stiffeners are considered under the boundary conditions, fixed but released in radial direction. The values are tabulated in. In the tables belowthe buckling load of the circular plate is increasing with increase in the number of stiffeners. And the buckling load is increasing with increase in the mode shape as shown in figure 19 as result from table3.

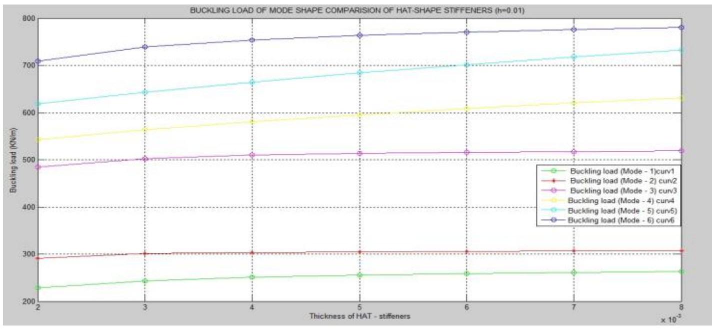

Figure 19: Buckling Load of Mode Shape of HAT-SHAPE STIFFENERS

Table 3: (Figure 19 & 20) Buckling Loads for HAT–Shape Stiffener

THICKNESS (m)	Axial Compressive Load (KN/m)	ONE - STIFFENER					
		1	2	3	4	5	6
0.002	20	228.7	291.84	483.94	542.7	618.02	708.38
0.003	20	243.56	300.8	502.58	563.42	643.12	738.76
0.004	20	250.6	303.64	509.52	580.5	664.64	753.68
0.005	20	255.02	304.98	513.24	595.38	683.98	763.36
0.006	20	258.12	305.78	515.62	608.52	701.66	770.44
0.007	20	260.46	306.3	517.28	620.24	717.88	775.9
0.008	20	262.88	306.66	518.5	630.72	732.8	780.28

The thickness of the stiffeners is increasing from 0.002 to 0.008 for all the three cross- section **(T, I, HAT - shape)** of the stiffeners. And also the numbers of stiffener with one, two and three stiffeners.

- With the increase in the number of **HAT-shape** stiffeners from **one to two,** the percentage increase in the buckling strength is from **23% to 24%** for **0.002m** thick stiffener. However the percentage increase in the buckling strength is from **55% to 57%** for **0.008m** thick stiffener.
- With the increase in the number of **HAT-shape** stiffeners from **one to three,** the percentage increase in the buckling strength is from **29% to 30%** for **0.002m** thick stiffener. However the percentage increase in the buckling strength is from **100% to 120%** for **0.008m** thick stiffeneras shown in figure 20 from table 3.

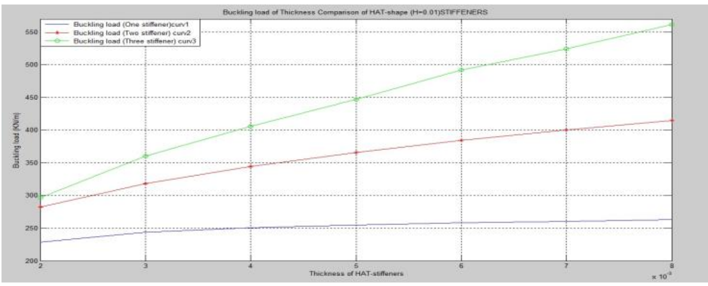

Figure 20: Buckling Load of Comparisons of HAT-Shape Stiffener

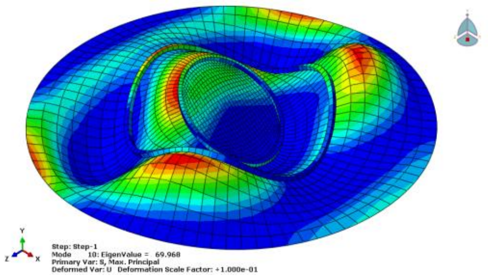

Figure 21: Deformed HAT-Shape, Two Stiffeners t=0.004m, h=0.01m for Mode - 10

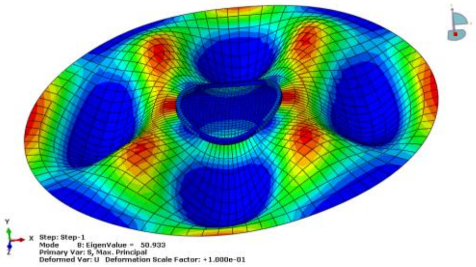

Figure 22: Deformed HAT-Shape, One Stiffeners of Thickness of Thickness t=0.008m, h=0.01m for Mode-8

CONCLUSIONS

In the present investigation, an attempt has been made to predict the failure of stiffened circular plate which is fixed but released in radial direction. The efficiency of different stiffeners on thin walled circular plates under axial compressive load was studied.Stiffeners of various cross sections were placed at different locations of circular plate to investigate their effectiveness while considering the economic aspects. The effect of positioning T, HAT and I-shaped stiffeners on thin walled circular plates was studied using numerical method. The numerical analysis has been performed using ABAQUS 6.10 software. In all the analysis, a Circular plate with T, HAT and I-shaped stiffeners is considered with the thickness and radius of the plate being constant. The thickness of stiffeners is increasing from 0.002 to 0.008 for all the three cross- section (T, I, HAT) of the stiffeners. And also the numbers of stiffener with one, two and three stiffeners,it is found that introducing a stiffening ring would result in higher buckling load, increased in the number of stiffeners, leads to increase in the strength, the effect of stiffeners configuration is very important since it can affect drastically the overall behavior of the plate.

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